Viking Mission Support

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In this article the final operations tests prior to Mars orbit insertion for Viking I are discussed together with the real-time operations support for the two months preceding this event. The report also covers several special operational strategies and procedures designed to optimize the DSN support during the critical planetary phases of the mission. The final phases of Network implementation for Viking and the support afforded to the radio science experiments and Mars radar observations are also included.

I. Implementation

Following the achievement of operational status in the Network Operations Control Center in late April 1976, a number of desirable but not essential features of the system still remained incomplete. In addition, operational usage of the facility soon revealed deficiencies that required attention in order to meet the increasing demands of the Viking mission as orbit insertion activity for Viking I approached. Using the task team that had been established to complete the initial phase of operational readiness, an accelerated work plan was initiated to cover the "enhancement items" for completion by June 1. The plan encompassed the following major items of software and hardware:

Software

(1) Modify the data records processor software to allow recall to be restarted just prior to an error received during a recall sequence.

(2) Install an updated magnetic tape handler program to increase the reliability of the recall merge process and reduce the size of data gaps.

(3) Correct the Network communications equipment to simultaneously route data to two Network telemetry monitors.

(4) Provide ability to synchronize on inverted telemetry data.

(5) Complete the Block III Network Command Subsystem to permit the stations to be configured for "commanding" from the Network Operations Control Center.

(6) Develop simplified algorithms to reduce the problems created by time regressions during the recall-merge process.

Hardware

(1) Replace the existing "borrowed" mag-tape assembly with permanent 4-drive units in the Network Data Processing Area.

(2) Convert four megadata display/keyboard terminals for use in the Network Operations Control Center to provide additional capability.

(3) Improve air-conditioning facilities for electronic rack cooling and Network data processing terminal.

(4) Upgrade star switch controllers for overwrite protection.

With the upgrade of the star switch controllers, the time regression problems appeared to be corrected and all work was completed by June 1. The enhanced system now provided much-improved edit, display and format facilities and was considered capable of supporting planetary operations, with adequate margin for failures and anomalies.

II. DSN Planetary Preparation Tests

The DSN planetary preparation test effort continued at an accelerated pace during the months of May and June 1976. The DSN Operations Planning Group conducted 19 Operational Verification Tests (OVT) and Ground Data System (GDS) tests and participated in four additional project tests during the period beginning May 1, 1976, and ending June 18, 1976. The basic objectives of OVTs and GDS tests are detailed in previous articles of this series. The tests supported were as follows:

A. DSN Tests

1. Operational Verification Test (OVT). One test of this type was conducted with DSS 43 during the first week of May for the primary purpose of increasing station operator proficiency. The other OVTs had been conducted during April. The Code 30 OVT is the standard planetary configuration test and uses the telemetry system to process six telemetry data streams from three Viking spacecraft (two Orbiters and one Lander simultaneously).

2. Automatic Total Recall System Block III (ATRS III) Operational Verification Test. Three ATRS III OVTs were conducted with DSS 12 at Goldstone and DSS 61 in Spain during May and June. Two tests were conducted with DSS 12, the second being a retest due to equipment problems which caused the failure of the initial test. One test was conducted with DSS 61. This test was designed to test the capabilities of the Automatic Total Recall Subsystem. Test objectives included recall of data from 7-track Digital Original Data Records (DODRs) in the automatic and manual modes, plus the conversion of Analog Original Data Records (AODRs) to DODRs and replay of these DODRs.

3. Configuration Code 61/15 Operational Verification Test. Five Code 61/15 tests were completed with 64-m DSSs during May and June. One was conducted with DSSs 14 and 43 and three were conducted with DSS 63 in Spain. The two additional tests with DSS 63 were scheduled at that station's request. The Code 61/15 OVTs are designed to simulate the configurations and procedures which will be used by a 64-m station designated as prime for Lander direct S-band link telemetry and command. The code 61 configuration uses two telemetry processing channels for Orbiter data and the remaining four for Lander direct link data. The code 15 configuration is used following the termination of the Lander direct link, using a second telemetry processor as a backup for Orbiter data.

4. Viking Orbiter Telemetry Decommutation Operational Verification Test. This test was completed with each of the 64-m DSSs. It was requested by the Viking Project, and its primary purpose was to demonstrate the ability of the stations to use the Viking Orbiter 75 Decommutation Program to decommutate and display selected engineering data words. The tests were conducted in conjunction with Viking tracking passes. Four engineering measurements were displayed at the stations and values compared in real-time with the values being displayed in the Viking Project Operations area. This program operates in the Digital Instrumentation Subsystem (DIS), Telemetry and Command Processor Assembly (TCP), or Simulation Conversion Assembly (SCA) computers at the DSS and would be used in the event of an emergency when the Project has lost the capability to process and display Orbiter engineering data. Key parameters would be selected with the values displayed at the DSSs being relayed to Project Operations by voice.

5. Configuration Code 1 (Modified) Operational Verification Test. This test was conducted with DSS 14 on two occasions. The code 1 (modified) configuration used the telemetry system to route Orbiter science data at data rates of 2 kb/s and lower through two telemetry strings and over a wideband data line and high-speed data line simultaneously. This provided two diversely routed transmission mediums, and in the event of a failure of the prime high-speed data line the data would continue to be transmitted to the Viking Project on the wideband data line. It will be used during Mars Orbit Insertion (MOI) of the first Viking Orbiter. DSS 14 was the prime DSS for this event.

6. Configuration Verification Tests. Configuration Verification Tests were conducted with DSSs 14, 43, and 63 in preparation for Orbit insertion of Orbiter A. These are engineering tests to verify that the configurations defined by the Network Operations Plan can be complied with and functionally checked. Following the successful completion of the CVTs, the DSSs designated as prime for MOI support (DSSs 14 and 63) were placed under configuration freeze. When the configuration freeze is applied, the stations are committed to Viking support only and can track no other spacecraft.

B. Viking Project Tests

1. Training Test Number Three (TT-3). The objective of TT-3 was to verify that the Viking Flight Team could detect and properly respond to selected spacecraft and ground data system failures or anomalous conditions which may occur during the period from separation of Mission A minus 52 hours, through separation. DSSs 43 and 63 supported this test using Configuration Code 15 with both telemetry processors initialized for Orbiter A. The second processor would be used for generating a backup Digital Original Data Record (DODR) and, in the event of a failure on the prime processor, could be redesignated as prime.

2. Ground Data System Test Number 11.0 (GDS 11.0). The primary purpose of GDS 11.0 was to test those capabilities, configurations, software and procedures not previously tested. The test was conducted with DSSs 14, 43, and 63 and included:

(1) Configuration code 61.

(2) Configuration code 1.

(3) Configuration code 15.

(4) Real-time playback of Analog Original Data Record (AODR) data.

(5) AODR-to-DODR conversion.

(6) Use of ATRS III software for automation recall.

(7) Production of Intermediate Data Records (IDRs).

(8) Manual command procedures.

(9) Tracking data for S- and X-band at all Viking-required sample rates and modes.

3. Ground Data System Test Number 11.0 Retest (GDS 11.0R). This test was scheduled due to failures during GDS 11.0 which prevented the successful completion of all test objectives. DSSs 43 and 63 were used during the retest and, for the most part, items tested were those associated with the non-real-time portion of GDS 11.0 such as AODR-to-DODR conversion and use of the ATRS III program for recall of DODR data. This retest was successful, and following its completion the GDS was certified as ready for Planetary Operations.

4. Mission Control Directorate Test (MCD). This test was requested by the Mission Control Director in order to give the Directorate personnel an opportunity to exercise procedures associated with the preseparation checkout and separation phases of the Viking mission. The test was supported by DSSs 14 and 63.

5. Operational Readiness Test Number 3 (ORT-3). The objective of this test was to demonstrate to the Viking Mission Director, the final readiness of all committed elements of the Viking Flight Operations System to support Mars Orbit Insertion of the Viking A mission. Where possible, the same personnel, hardware, software, configurations, etc., used in support of ORT-3 were to be used in support of the actual mission event. The 64-m subnet was used to support this test, with DSS 14 performing the MOI command load update and DSS 63 supporting the simulated MOI.

With the successful completion of ORT-3, the project test effort for Planetary Operations has been completed. The DSN plans to conduct two additional OVTs with DSS 14 just prior to the first direct S-band link from Lander A in order to exercise configuration code 61 and certify DSS 14 for this mission phase.

III. DSN Support of Cruise Operations

A summary of the major cruise support activities is provided in this section.

A. Significant Mission Events

Table 1 lists the significant Viking cruise activities that have been supported by the Network during the period of this report. Many of the spacecraft activities required the transmission of large numbers of commands and/or processing of multiple telemetry streams, including the highest Viking data rate (16.0 kp/s) by the stations. These activities also imposed a workload on the Network Operations Control Center (NOCC) and Ground Communications Facility (GCF) far beyond that which would be expected in a normal "quiet cruise."

B. DSS Support

While Table 1 illustrates the magnitude and complexity of the Viking mission events supported by the DSN, Table 2 depicts the extent of support provided by the Deep Space Stations in terms of the total number of passes, tracking hours, and commands transmitted. No major Network outages occurred during the reporting period.

C. Network Operations Control Center (NOCC) Operations

NOCC implementation for Viking support configuration was concluded on April 26, and all resources were assigned to accomplishment of selected enhancement features of the existing systems. The enhancement effort was completed on May 31, and the NOCC capabilities existent at that time will be under configuration control for the remainder of the Prime Viking Mission. The NOCC existing capabilities are the minimum required to meet the DSN commitment to Viking planetary operations and are considered adequate. System maturity and operator experience are contributing to increased proficiency in the operation of the NOCC on a continuous basis. Training in Intermediate Data Record (IDR) production is considered to be 100 percent complete.

D. DSN Discrepancy Report Status

Table 3 summarizes failures and anomalies in Viking committed Network resources as documented by the Discrepancy Report (DR) System during the period of January 1 through May 30, 1976. The station-dependent number is unusually high due to continued development of new capabilities which are being demonstrated for the first time in support of the Viking Project. The remaining open DRs are under active investigation and are of no immediate impact to operations.

IV. Operations Strategies for Viking I Planetary Phase

A. General

A plan has been devised by the DSN Tracking Analysis Group and coordinated with the Ops Planning Group and Viking Project for three main events of the Viking 1 planetary phase. These events are Mars Orbit Insertion, landing, and daily periapsis passages. The strategies are fully documented in the Network Operations Plan for the Viking Project and are described in lesser detail here.

1. Mars Orbit Insertion tracking strategy. In order to properly align the Viking 1 spacecraft so that its 43-min Mars Orbit Insertion (MOI) motor burn places it into the correct Mars-centered orbit, the spacecraft will go through a sequence of three turns: a roll turn, a yaw turn, and a second roll turn. The combination of the resulting geometric orientation (unfavorable cone and clock angles) and the use of the low-gain antenna will cause the loss of both the uplink and downlink signals from shortly after the start of the yaw turn until the end of the second roll turn and return to the high-gain antenna. Following the burn, the spacecraft will go through the same turns in reverse order to restore it to its original orientation.

The MOI motor burn will nominally have the following characteristics:

(1) Burn start 15:54:01 GMT

(2) Burn stop 16:37:14 GMT

(3) Magnitude (Δ) 1245 m/sec

A profile of the two-way doppler rate of change (DD2) during the burn may be seen in Fig. 1. Additionally, Figs. 2 and 3 illustrate the effect of the burn and subsequent periapsis passage on the exciter frequency (XA) (in DSS transmit time) and the two-way doppler (Earth receive time, ERT).

2. Pre-MOI burn strategy. The pre-MOI motor burn uplink strategy has been designed with the intent of acquiring the spacecraft receiver at the earliest possible time, perhaps before the switch back to the high-gain antenna, with its subsequent return of the downlink signal.

Figure 4 illustrates this tuning strategy along with a nominal time line. The procedure for a nominal burn (start time 15:54:01 GMT) is as follows:

(1) Start tuning	14:40:00 GMT	
(2) Tuning rate	0.0182 Hz/sec	Digital Controlled Oscillator (DCO)
(3) Start frequency	43993800 Hz	(DCO)
(4) Start insurance sweep	15:07:00 GMT	
(5) End insurance sweep	15:09:00 GMT	
(6) Sweep lower limit	43993730 Hz	(DCO)
(7) Sweep upper limit	43993920 Hz	(DCO)
(8) Tuning rate	2 Hz/sec	(DCO)

Because of unfavorable antenna orientation, the downlink signal level will gradually degrade to approximately −186 dBm during the yaw turn and further decrease during the second roll turn. It will be necessary then to quickly acquire the signal after the end of the roll turn in order to have solid telemetry lock throughout the Ground Data System before the start of the burn.

To accomplish this, the station will sweep the prime receiver (Receiver 3, Block IV) at a high rate, using the acquisition (ACQ) mode with the acquisition-to-zero (ATZ) signal enabled. The sweeping will start 5 min before the end of the roll turn in order to ensure receiver lock as early as possible.

3. Post-MOI burn strategy. The post-MOI burn uplink strategy consists of a single sweep at a rate of 2 Hz/sec. This sweep will effectively cover the exciter frequency (XA) plus 80 Hz and minus 50 Hz, to accommodate any trajectory uncertainties as a result of the burn. Start time of the sweep is 1 min after the start of the roll turn unwind and is coincident with the loss of downlink due to the turn.

For the nominal June 19 burn, the post-MOI burn uplink acquisition procedure is as follows:

(1) Start tuning	16:42:00 GMT	
(2) Start frequency (TSF2)	43993920 Hz	(DCO)
(3) Tuning rate	2 Hz/sec	(DCO)
(4) End frequency (TSF2)	43993640 Hz	(DCO)
(5) Sweep duration	2 min 20 sec	

The post-MOI burn tuning is shown in Fig. 2.

To insure quick acquisition whenever the downlink signal level increases to above threshold, the receiver will be swept through a region of frequencies corresponding to one-way doppler (D1) plus and minus 10 kHz at a rate of 2 kHz/sec at S-band.

Nominal time line and frequencies for June 19 were:

(1) Start sweep	17:00:00 GMT	
(2) Upper limit	44677000 Hz	(DCO)
(3) Lower limit	44676000 Hz	(DCO)
(4) Rate	100 Hz/sec	(DCO)

The post-MOI burn uplink reacquisition sweep was designed with the intent of allowing the Flight Path Analysis Group to observe the motor burn in the doppler data unperturbed by changes in the receiver reference frequency. However, if it becomes necessary to reacquire the uplink so that commands may be transmitted at the earliest possible time, the reacquisition sweep may be advanced to occur coincident with the yaw unwind (transmit time) without any change in sweep frequencies. This will, of course, obscure the signature of the burn in the doppler. Additionally, if the reacquisition sweep fails to acquire the spacecraft receiver, a second uplink sweep of plus and minus 50 Hz will be sufficient to insure acquisition.

The current plan calls for a postburn receiver acquisition sweep of frequencies corresponding to one-way doppler plus and minus 10 kHz at a rate of 2 kHz/sec at X-band. However, owing to the low signal level (−161 dBm) expected at that time, this rate will be too high to successfully acquire the downlink.

B. Lander Acquisition Strategy

1. Uplink Acquisition. Approximately 16 hours after the first Viking lander has touched down on the surface of Mars, DSS 14 will commence the initial direct link with the lander. This acquisition as well as subsequent acquisitions has the following characteristics:

(1) The uplink acquisition will be made in the "blind."

(2) Two receivers, each connected to a different antenna and with a 15- to 20-dB difference in signal level, are to be acquired.

(3) There will be, initially at least, large frequency and temperature uncertainties.

(4) The total acquisition time will be limited.

In order to accommodate these characteristics, very conservative uplink and downlink acquisition strategies have been devised. These strategies are for the initial direct communications system (DCS) link but are, for the most part, applicable to all subsequent lander DCS links. Figures 5 and 6 illustrate time lines for the short and long DCS links.

The starting frequency of the sweep will be chosen such that the start frequency and channel center frequency are in the same direction away from the receiver best lock frequency (XMTREF). Thus, for example, the initial acquisition sweep will start 470 Hz above the channel 13 center frequency (or 22010589 Hz) since the XMTREF is approximately 16 Hz above the center frequency. Upon completion of the sweep, the station will tune to a tracking synthesizer frequency (TSF) chosen to minimize the phase error in the primary command receiver during the remainder of the DCS link. 48 Hz/sec $<$ frequency rate $<$ 219 Hz/sec will be employed.

2. Downlink acquisition. Because of temperature and power constraints the Viking Lander S-band transmitter will be turned on for at most 92 min (for long DCS links) starting approximately 70 min after the completion of the uplink acquisition sweep. It is therefore necessary to sweep the receivers in such a manner as to quickly acquire the two-way downlink and to allow for the acquisition of a one-way downlink as a contingency.

The sweep should start approximately 5 min before the time that the downlink signal is expected to be seen. Using this high sweep rate, the entire range of frequencies will be swept approximately every 12 sec. The typical receiver sweep frequency range is given in Table 4, which provides a summary of all acquisition parameters.

V. Mars Radar Support

During this reporting period (May, June) the X-band Mars radar facility at Goldstone continued to support an intensified program of observations. The early observations continued previous coverage of the Viking "C-sites," and in June, the view periods began to cover the prime landing "A-sites." Observations were made on the following days with the results tabulated on Table 5.

During the period of these observations, the received signal level decreased significantly due to the increasing Earth–Mars range. Typical C-1 site data taken around April 10, 1976, are compared with typical A-1 site data taken two months later, on June 11 (Figs. 7 and 8).

The quality of the A-1 site observations was enhanced by the additional radar coverage provided by the S-band radar at the Cornell Radio Astronomy Observatory at Arecibo, Puerto Rico. The overlapping areas of coverage for prime A-1 and A-2 landing sites are shown in Figs. 9 and 10.

With these observations, the X-band radar support for the 1976 opportunity totalling 527 hours was concluded. The radar data were intensively analyzed by the Viking Landing Site Selection Group in its landing site selection processes. At the time the radar observations concluded on June 15, the Viking Project decided to await the first of the site certification pictures from Orbiter 1 to correlate with the Goldstone and Arecibo radar data before making the final decision on the actual landing site.

VI. Radio Science

During the months of May and June, three occultation demonstration passes were carried out with DSS 14 and 43. The first two tests on May 12 and 15 produced good data that were processed through the entire system and provided a satisfactory demonstration of end-to-end operation. The third test, on May 31, utilizing both DSS 14 at Goldstone and DSS 43 in Australia simultaneously was a failure due to procedural and predict problems. Corrective action has been taken and further tests are scheduled.

The very long baseline interferometry tests using the Viking spacecraft and a quasar (PO 735+17) had experienced tape recorder problems on five successive passes on April 18, 24, and 28 and May 3 and 7. After several unsuccessful attempts to correct the problem at the stations, it was decided that specialist help was needed, and late in June an engineer was sent to the site to investigate the problems.

Table 1. Viking significant events supported by the DSN

Date, 1976	Spacecraft	Activity
March 26	Lander 2	Inertial reference unit (IRU) No. 2 calibration
27	Orbiter 1	High-gain antenna (HGA) calibration
April 11	Orbiter 1	Software update
12	Orbiter 1	Scan calibration No. 2
14	Orbiter 2	Software update
15	Orbiter 2	Scan calibration No. 2
16	Orbiter 2	Visual Imaging Subsystem (VIS) picture playback and Lander 2 maintenance
17	Orbiter 1	VIS playback
17	Lander 1	Battery charge and tape recorder maintenance
18	Orbiter 2	VLBI with Orbiter 2 and quasar source
20, 21		Demonstration Test No. 4 (DT-4)
23, 24	Lander 1	ICL update
23–26	Lander 1	Battery conditioning sequence
26–29		Training Test Number 5 (TT-5)
May 1, 2	Orbiter 1	Photo calibration and playback sequences
3		TT-3
3	Orbiter 2	Quasar VLBI
5–7	Orbiter 1	ICL update and battery conditioning sequence
8	Orbiter 1	IRTM playback
8, 9, 11	Orbiter 1	Photo calibration 2 playback
12	Orbiter 2	MAWD calibration
13, 14	Lander 1	Battery conditioning sequence
15–18	Lander 2	Battery conditioning sequence
17–20	Orbiter 1	ONS No. 1
19–20	Lander 1	Battery conditioning sequence
21	Lander 1	Battery conditioning
21, 22	Orbiter 2	16 kbs playback
23–26	Lander 2	Battery conditioning
24, 25	Orbiter 2	16 kbs playback
25	Orbiter 1	Gyro and accelerometer calibration

Table 2. DSS support of Viking cruise operations

Month, 1976	DSS	No. of passes	Hours tracked	Commands transmitted
April	11	33	223:39	392
	12	33	236:42	588
	14	1	08:38	20
	42	32	164:03	0
	43	0	0	0
	44	29	194:04	9
	61	33	241:07	45
	62	7	69:43	0
	63	23	208:53	2206
Monthly total:		191	1346:49	3260
May	11	29	217:40	753
	12	25	176:47	490
	14	11	69:37	15
	42	30	214:12	9
	43	24	184:32	574
	44	9	62:27	447
	61	32	281:24	233
	62	4	36:44	28
	63	28	287:55	6274
Monthly total:		192	1531:18	8823
Report total:		383	2878:07	12,083

Table 3. Viking DR summary matrix: January 1, 1975–May 30, 1976

	DSS										DSN	GCF	NDPA	NOCA	total	%
	11	12	14	42	43	44	61	62	63	71						
Resolution Station-dependent	25	36	118	34	89	22	28	25	86	16	5	27	51	45	607	84.4
Station-independent	4	7	10	7	3	0	2	4	6	1	4	7	13	14	82	11.4
Other or unavoidable	2	2	2	0	1	0	0	1	0	1	14	4	1	2	30	4.2
Total DRs closed	31	45	130	41	93	22	30	30	92	18	23	38	65	61	719	
Total DRs generated	43	47	136	48	100	22	30	30	120	18	27	40	123	70	854	
DRs opened as of May 30, 1976	12	2	6	7	7	0	0	0	28	0	4	2	58	9	135	

Table 4. Receiver sweep frequency range

Uplink acquisition sweep	
TXR on	18:24:00 GMT
TXR power	20 kW
Frequency	44022654.0 Hz
Start tuning (time ϕ)	18:24:36 GMT
Tune to	44020773.0 Hz
Tuning rate (rate ϕ)	−1.0000 Hz/sec
Time (time 1)	18:55:57 GMT
Tune to TSF	44021700.0 Hz
Tuning rate (rate 1)	+1.0000 Hz/sec
Stop tuning (time 2)	19:11:24 GMT
CMD MOD on	19:12:00 GMT
RNG MOD on	20:35:00 GMT
Sweep duration	46 mins 48 sec
Downlink acquisition sweep	
Start sweep	20:24:00 GMT
Sweep upper limit	44752749.0 Hz
Sweep lower limit	44751349.0 Hz
Sweep rate	100 Hz/sec
Ranging parameters	
Tϕ	21:12:02 GMT
T1	9 sec
T2	9 sec
T3	10 sec
RTLT	36 mins 38 sec
Components	15

Table 5. Goldstone X-band Mars radar observations

Observation date, 1976	Site	Data quality
May 10	Terrain calibration	Partial pass given to Helios
12	Terrain calibration	Good data
14	Terrain calibration	Good data
19	Terrain calibration	Good data
26	Terrain calibration	Good data
29	A-1	Good data
30	A-1	
31	A-1	Good data
June 1	A-1	No pass
2	A-1	No pass due to ORT-3 support
3	A-1	Good data
4	A-1	Good data
5	A-1	Good data
6	A-1	Good data
7	A-1	Good data
8	A-1	Bad data due to transmitter problem
9	A-1	No pass due to midcourse maneuvers
10	A-1	No pass due to optical nonsupport
11	A-1 & A-2	Good data
12	A-2	Good data
13	A-2	Partial pass, good data
14	A-2	Partial pass, good data
15	A-2	No data due to transmitter failure

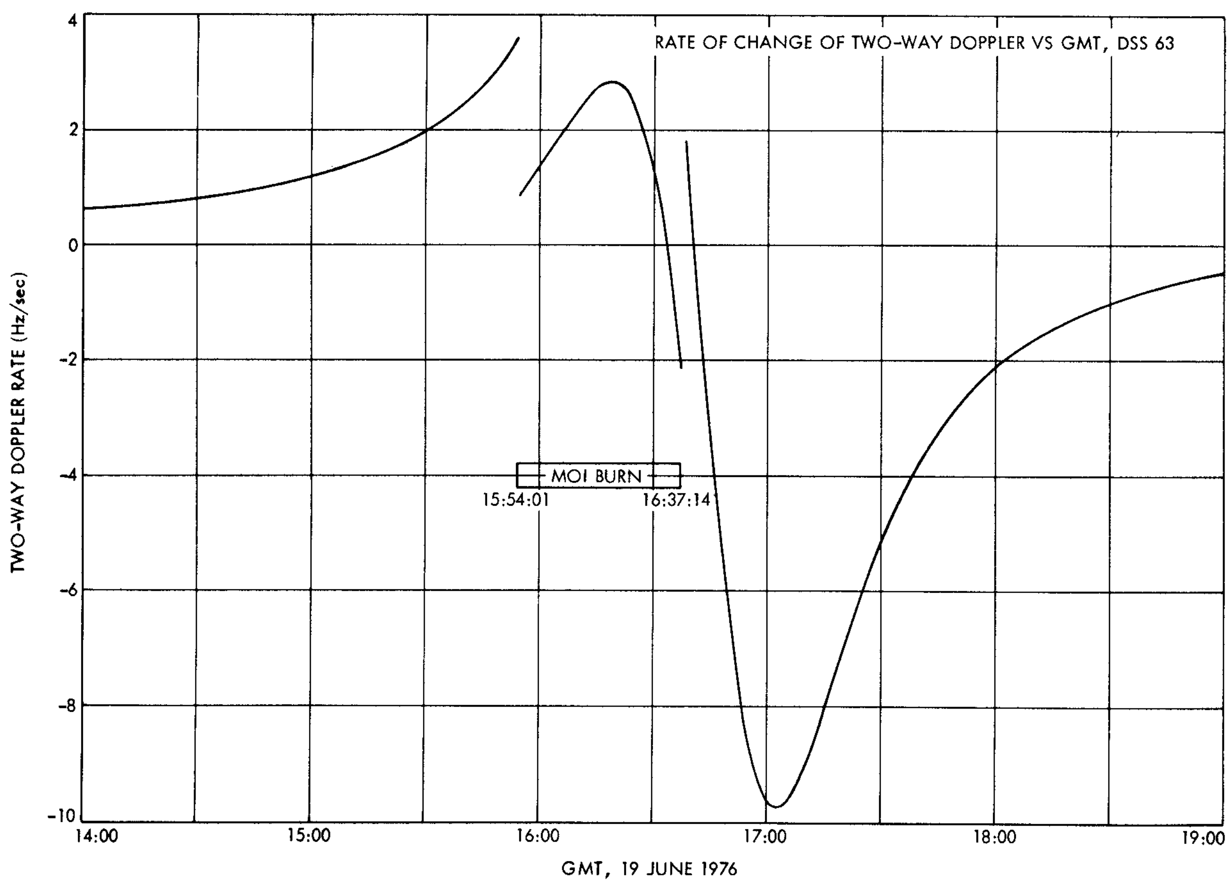

Fig. 1. Rate of change of two-way doppler vs GMT, DSS 63

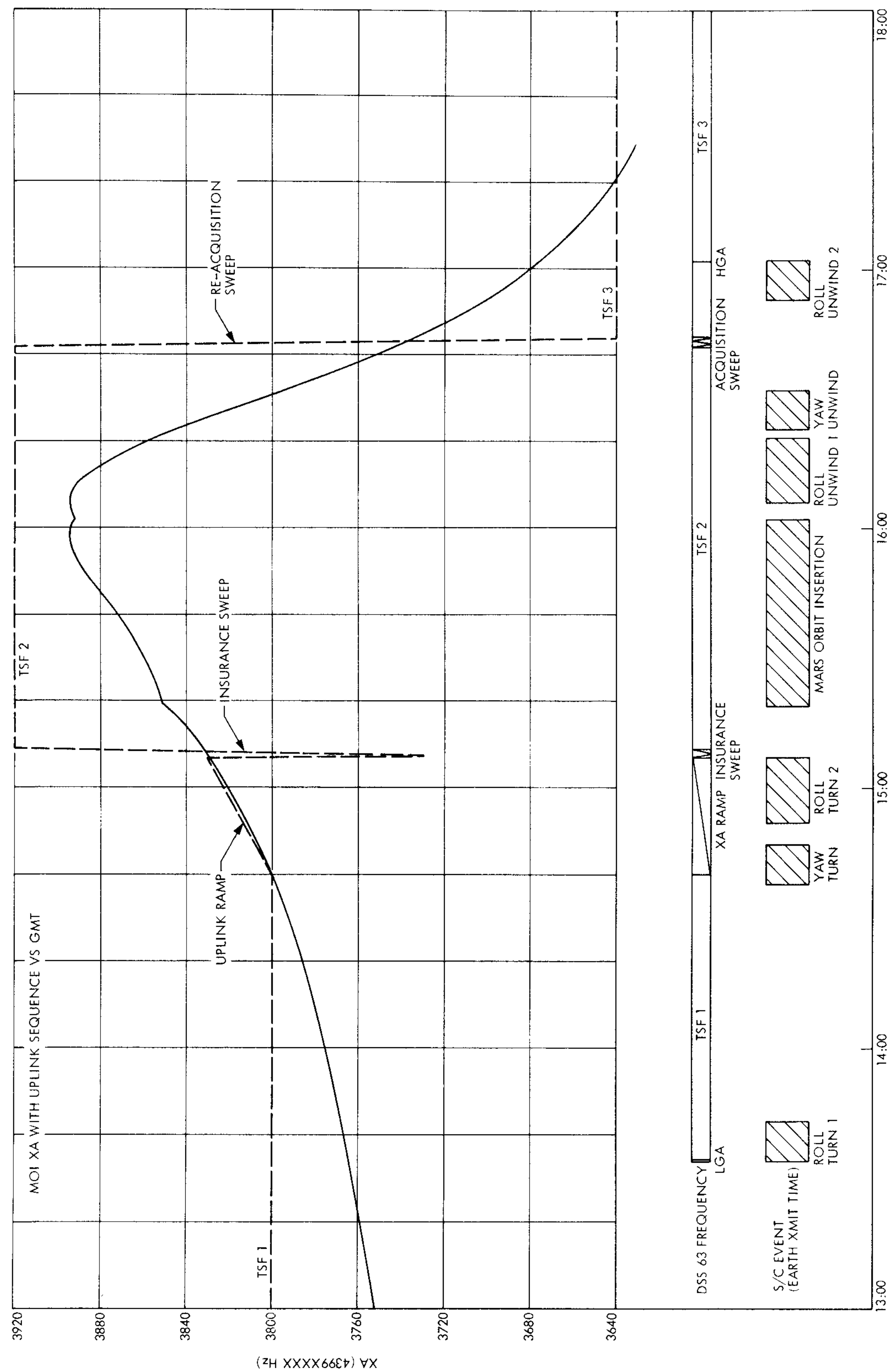

Fig. 2. Mars Orbit Insertion XA with uplink sequence vs GMT

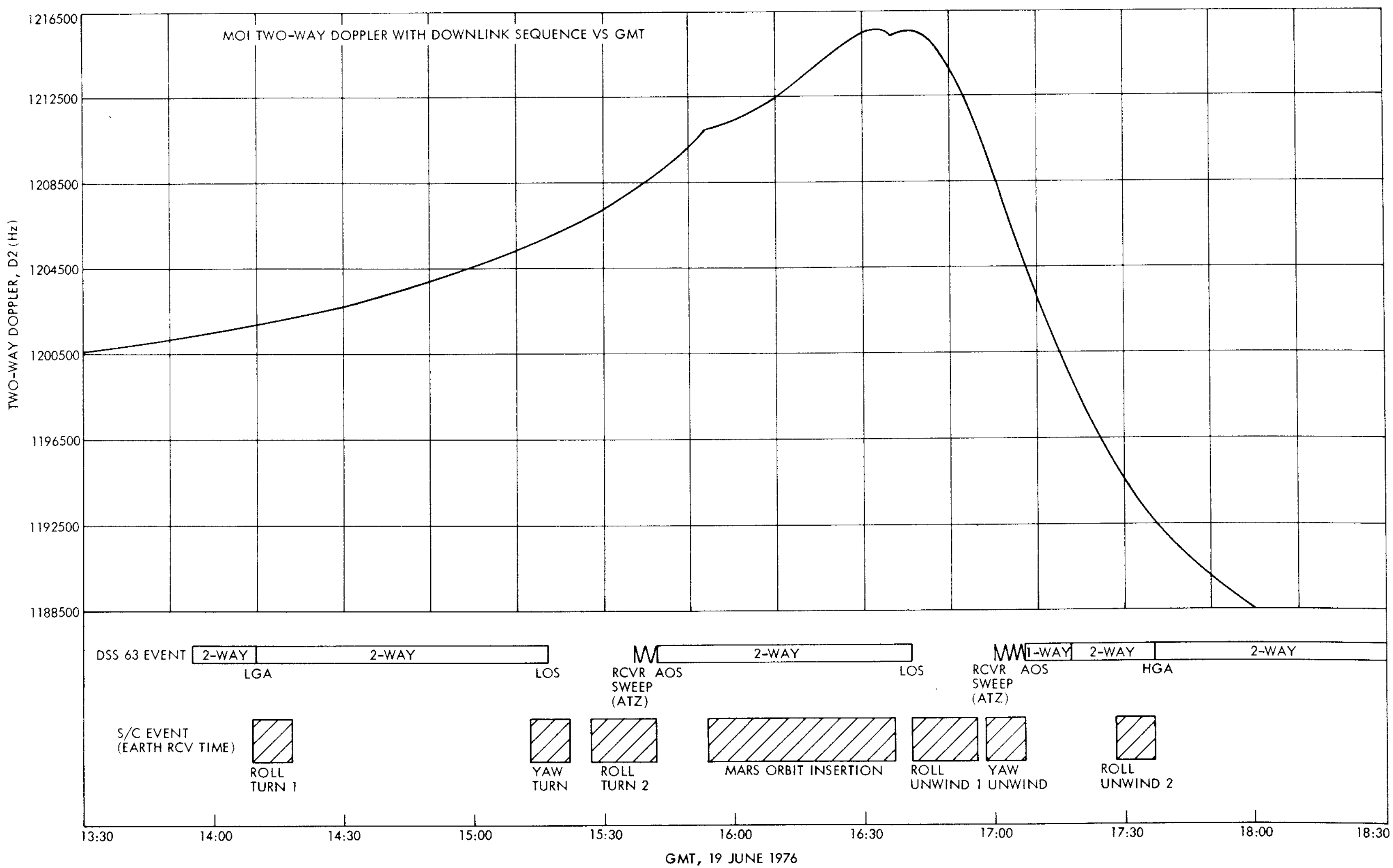

Fig. 3. Mars Orbit Insertion two-way doppler with downlink sequence vs GMT

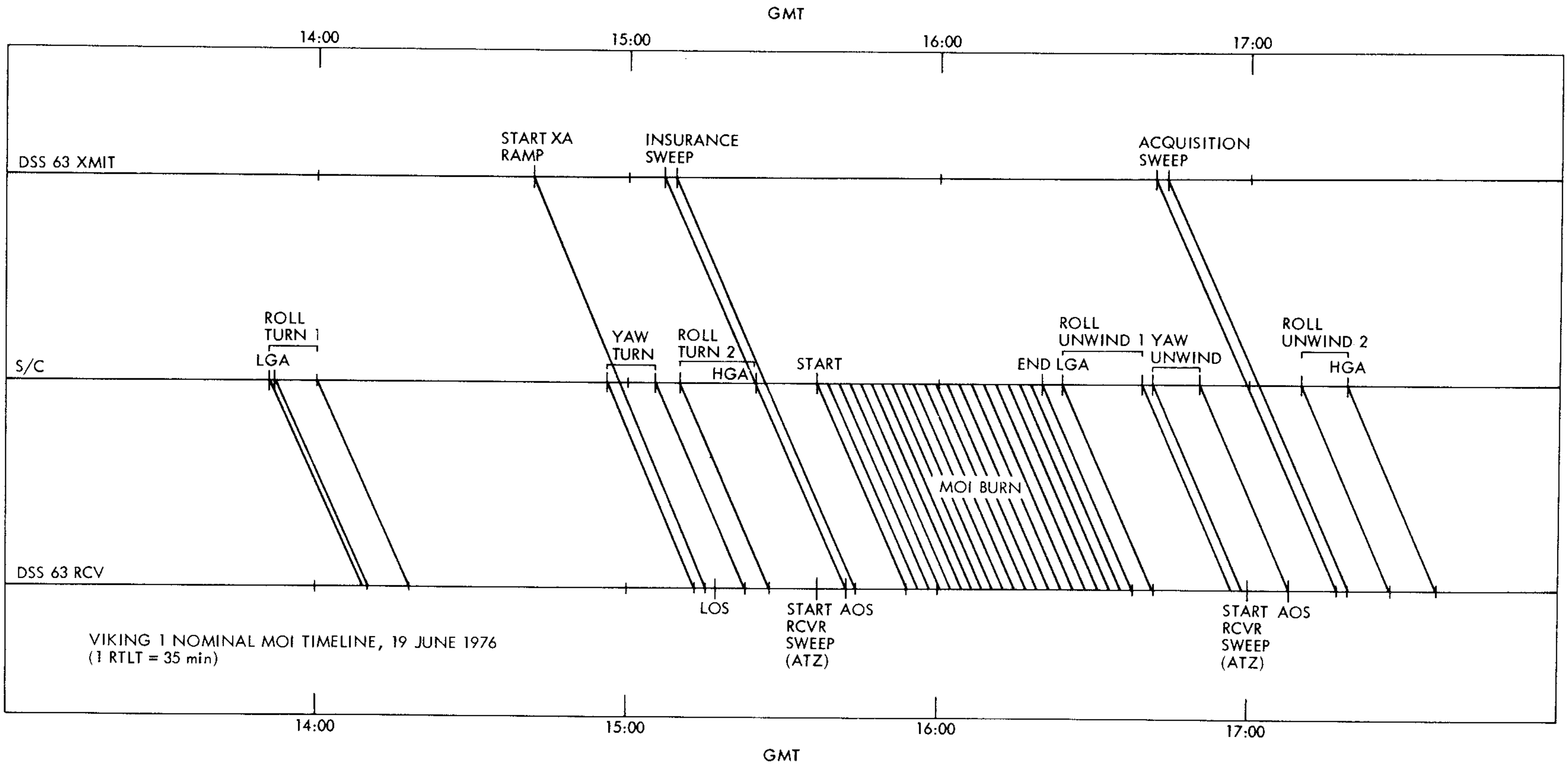

Fig. 4. Viking 1 nominal Mars Orbit Insertion timeline, June 19, 1976

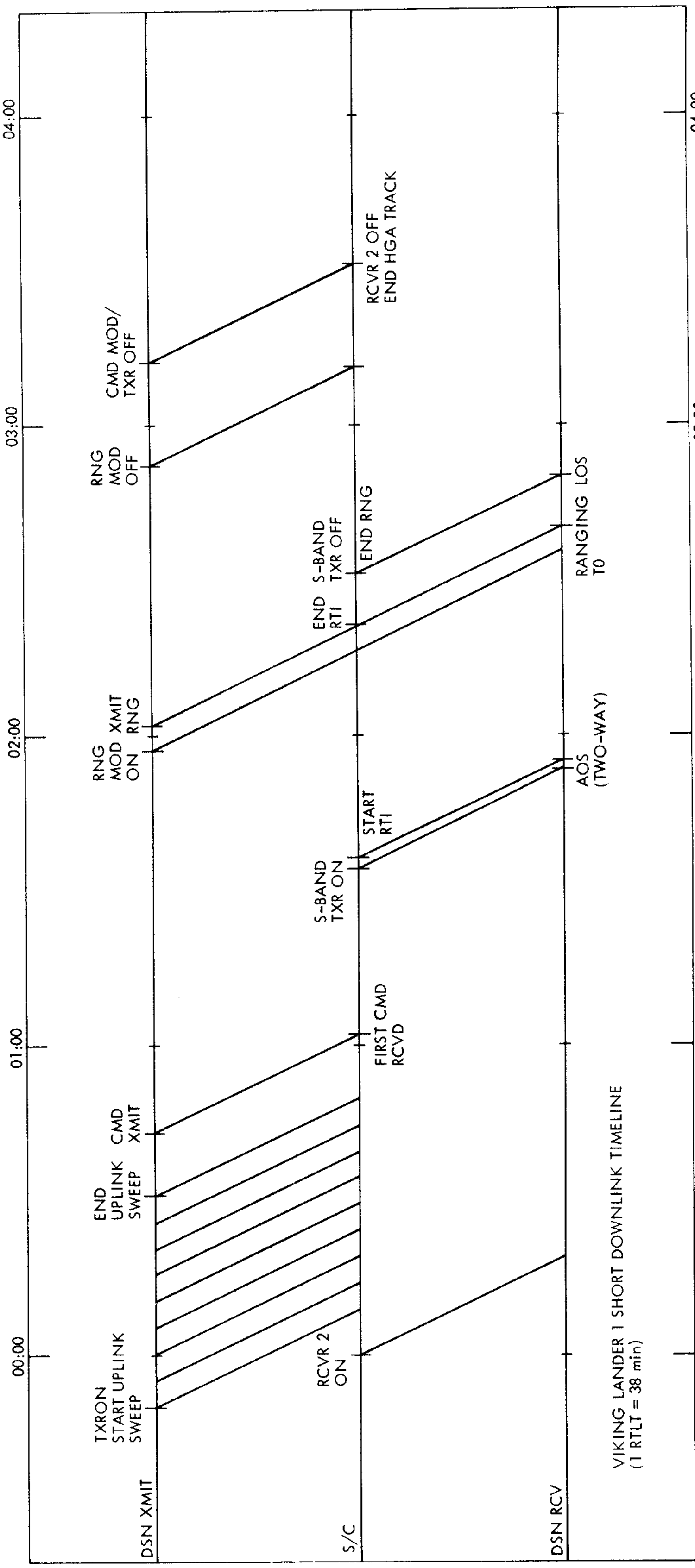

Fig. 5. Viking Lander 1 short downlink timeline

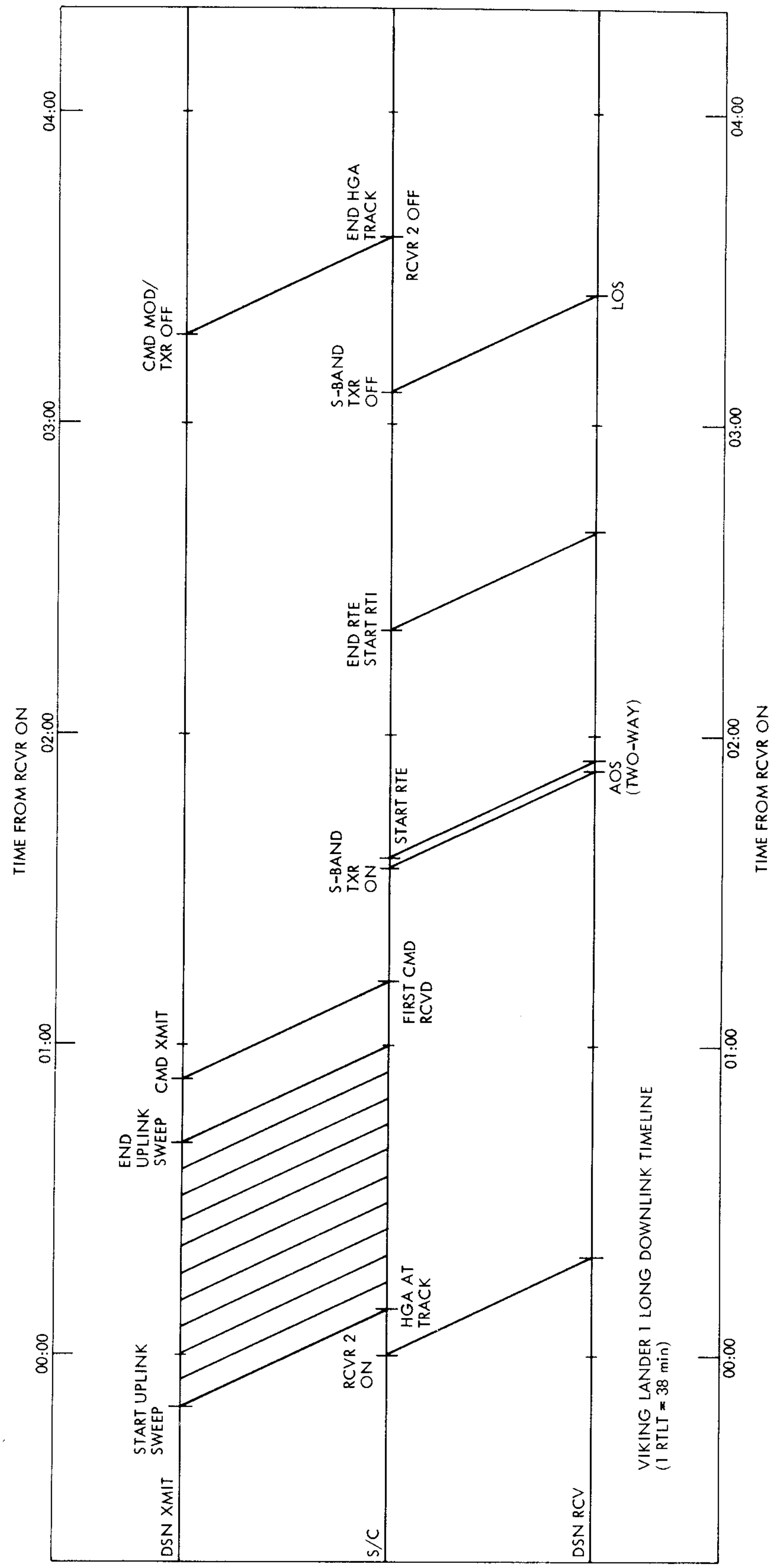

Fig. 6. Viking Lander 1 long downlink timeline

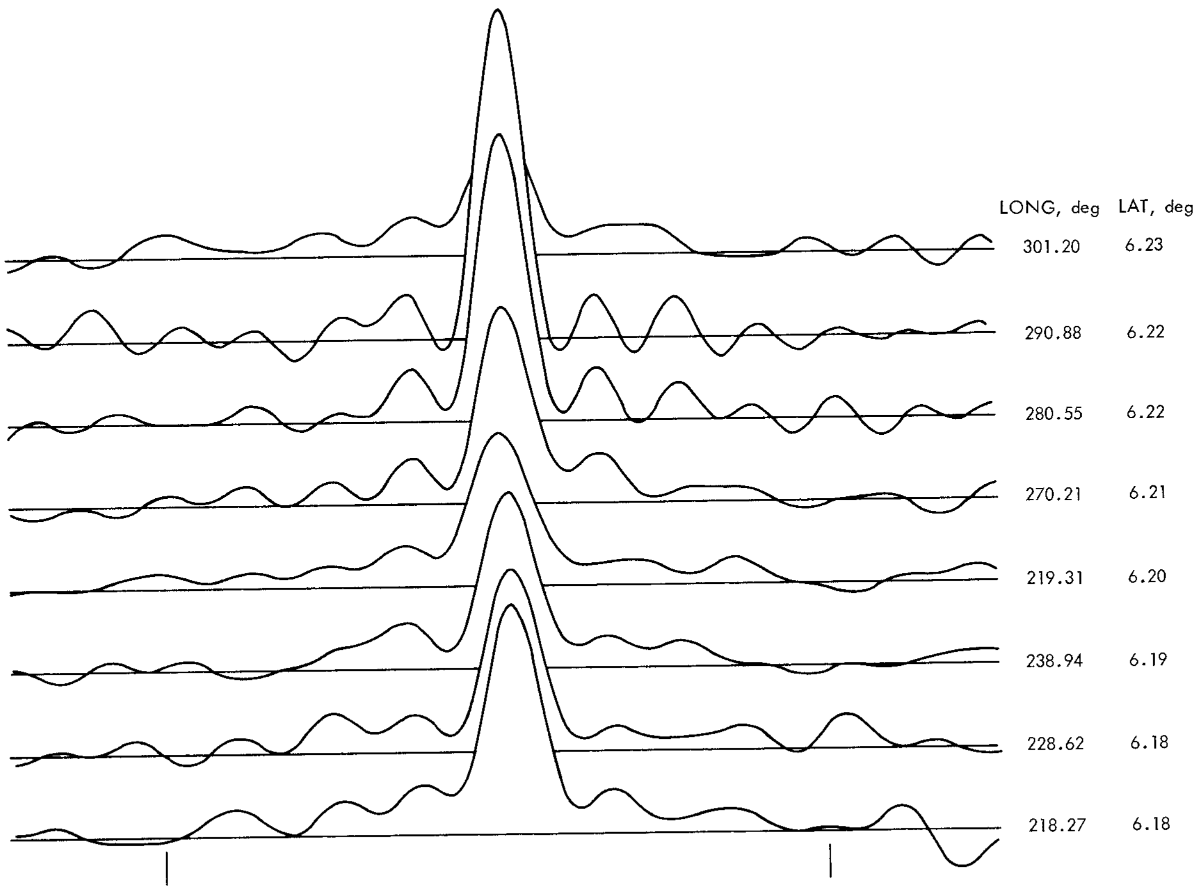

Fig. 7. X-band radar spectra from the Viking C-site observations of April 19, 1976

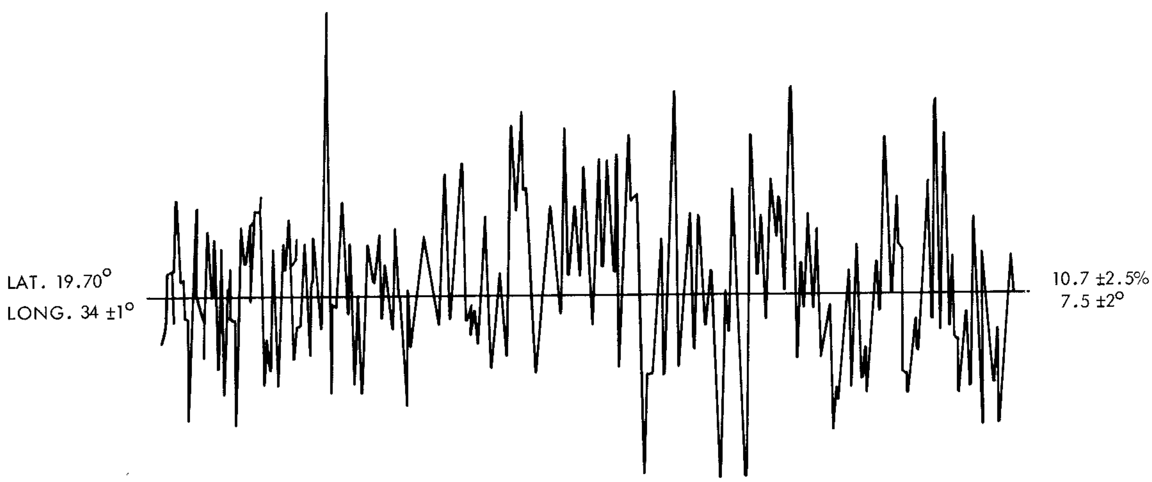

Fig. 8. X-band radar spectra from the Viking A-site on June 11, 1976

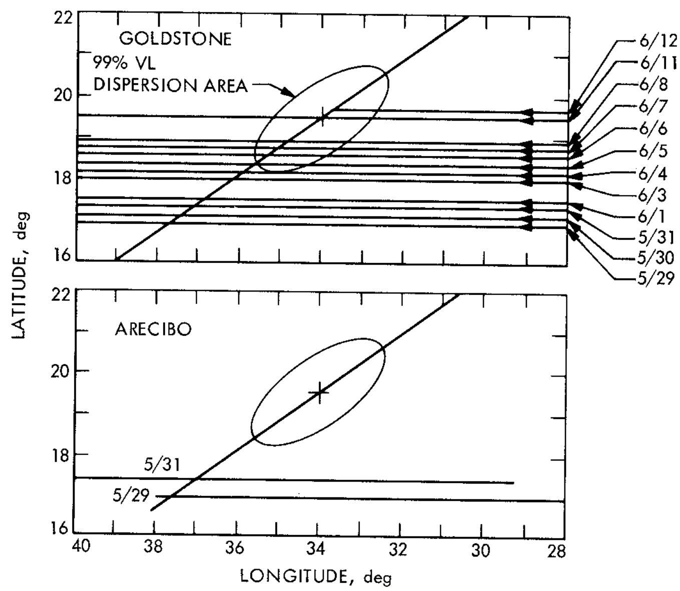

Fig. 9. A-1 radar observations, May–June 1976

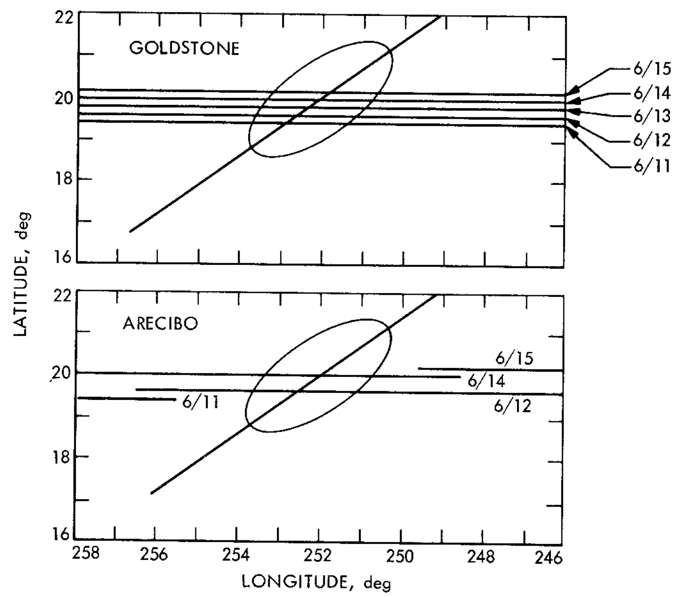

Fig. 10. A-2 radar observations